



Performance and Safety of Lithium-ion Supercapacitors

Judith Jeevarajan, Ph.D. and Martin Martinez

NASA-JSC, Houston, TX

Dr. Jae Sik Chung, James Park and Kwang Jung

PCTest Engineering

James Banas, Jeff Myron

JSC Micro, Inc.

November, 2012

2012 NASA Battery Workshop

Background

- Li-ion supercapacitors manufactured by JSMicro, Inc. were purchased and tested for performance and safety.
- The li-ion supercap has a operating voltage range of
- Operating Range: 3.8 V to 2.2 V; can charge up to 4.2 V if necessary

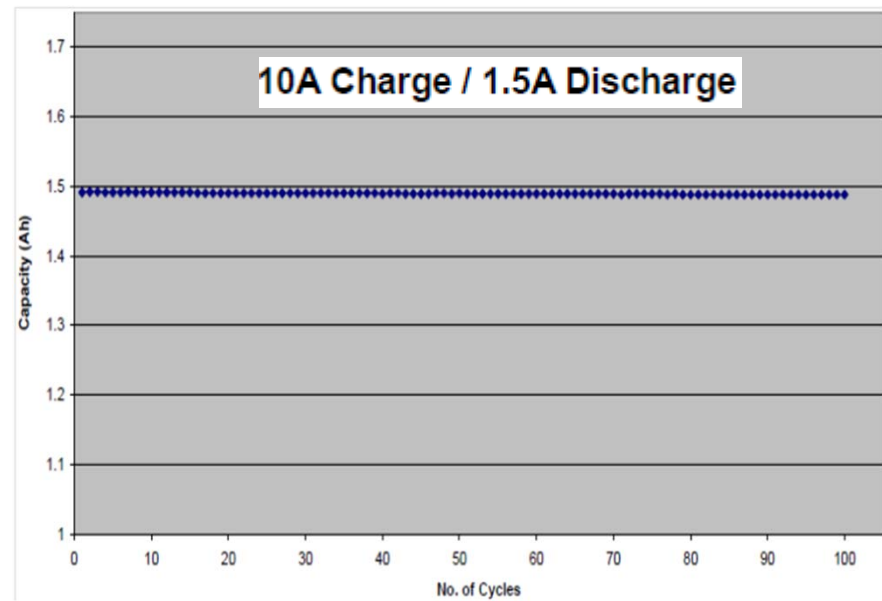
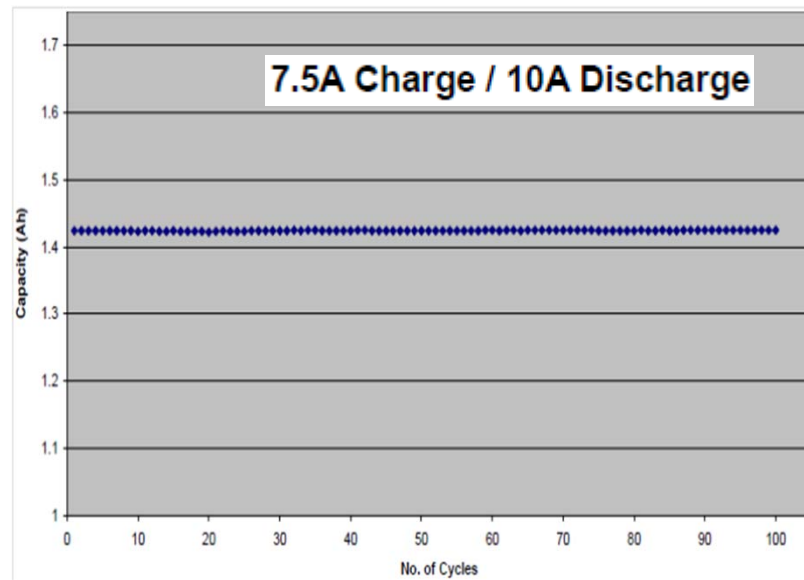
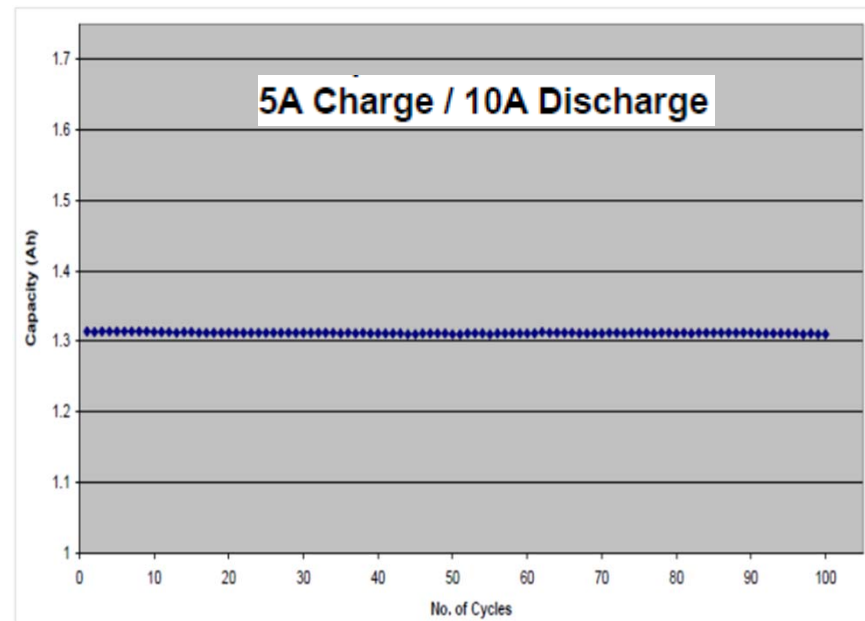
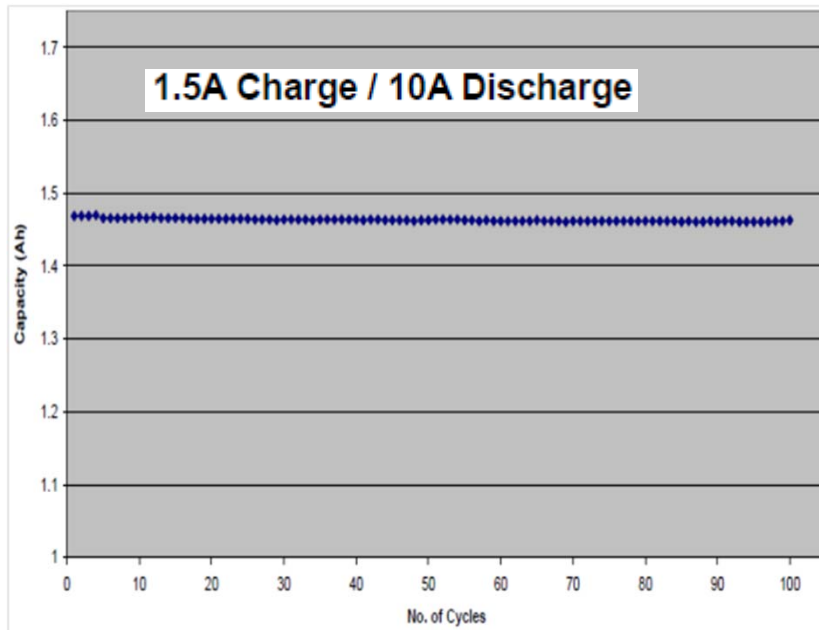


Capacity: 1 Ah

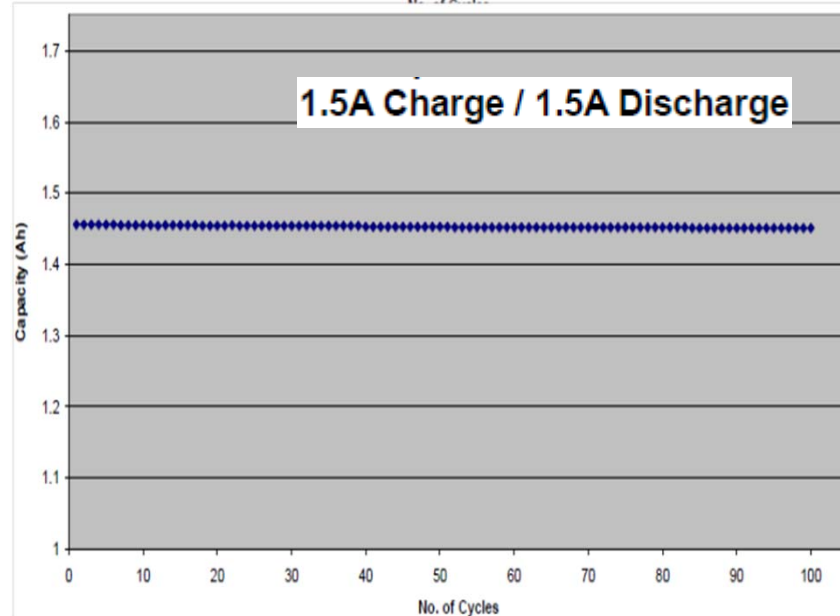
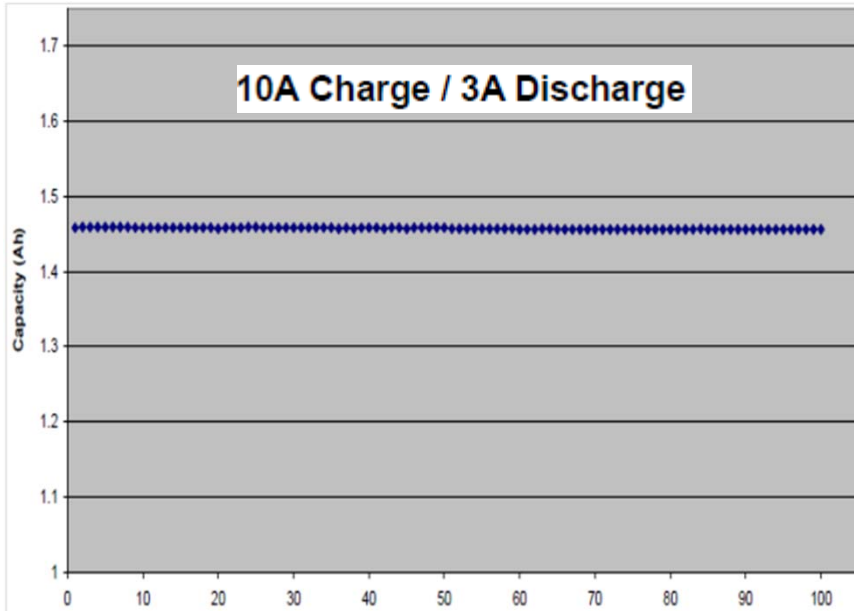
Dimensions: 93 mm (length); 15.5 mm (width); 149.5 mm (height)

Mass: ~370 g

Rate Capability Tests

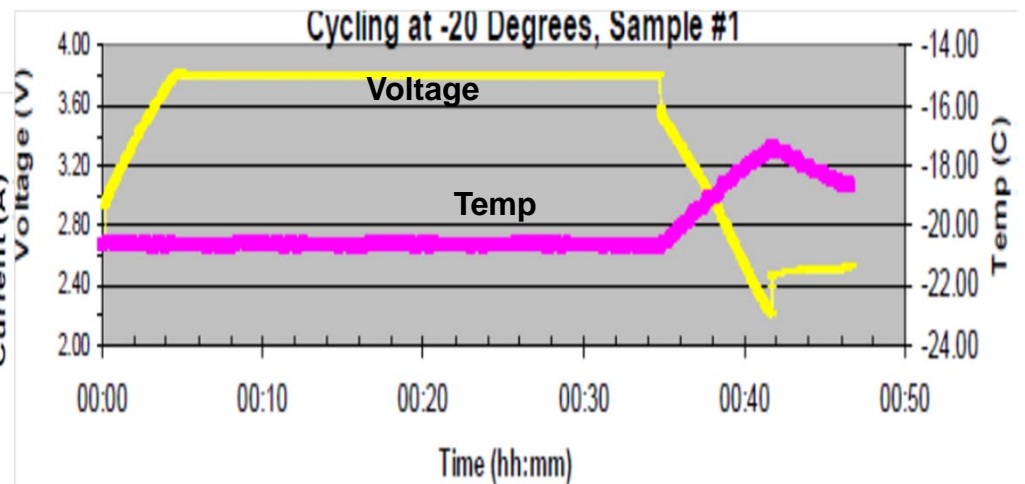
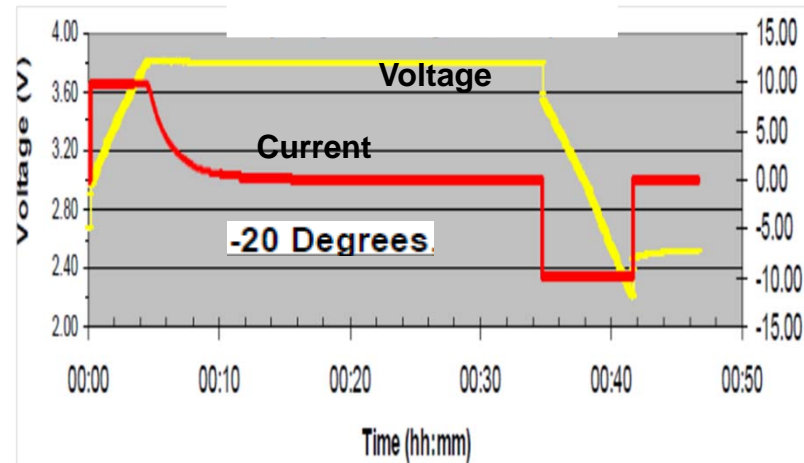
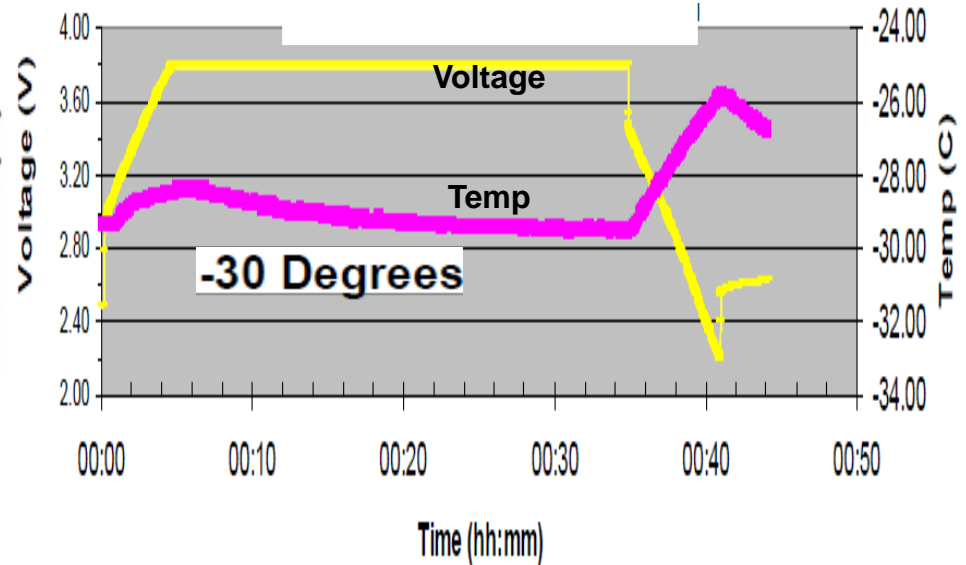
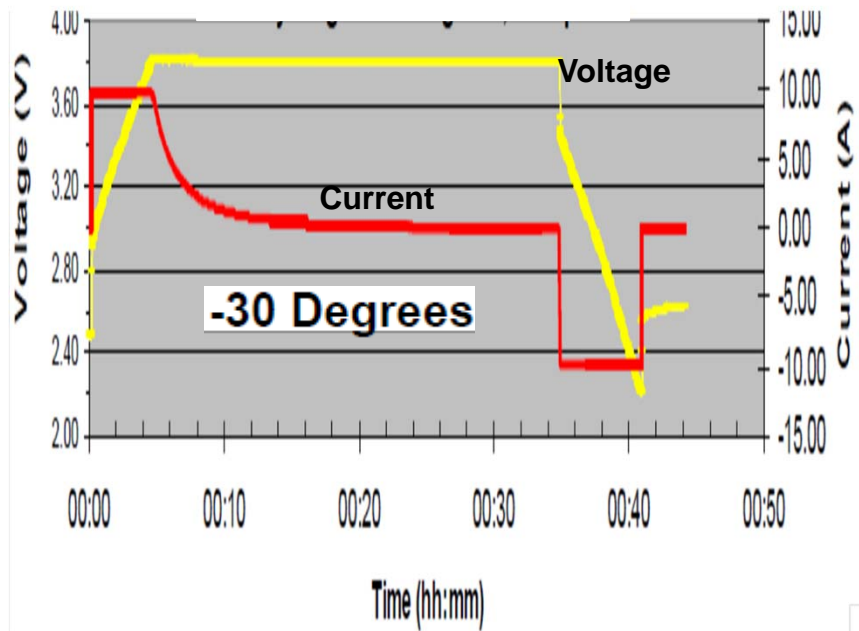


Rate Capability Tests

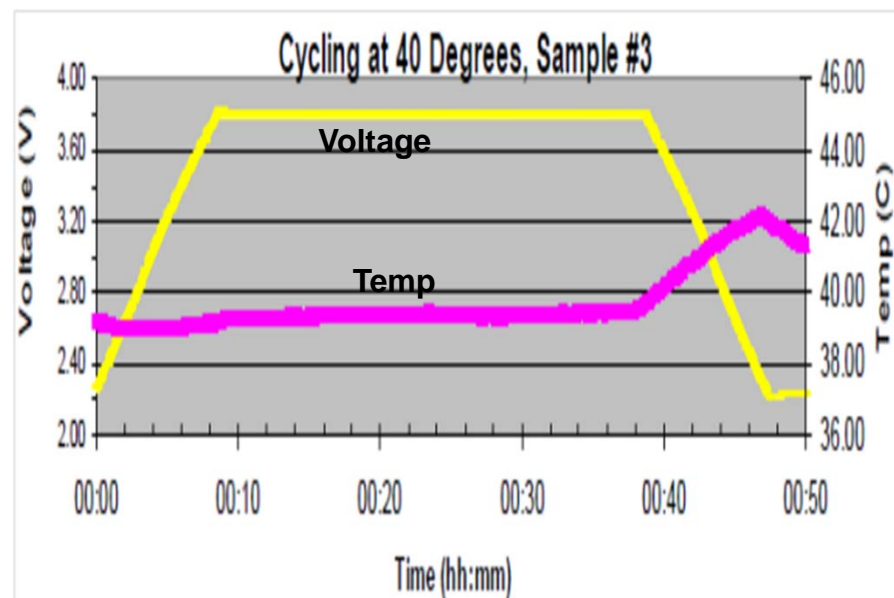
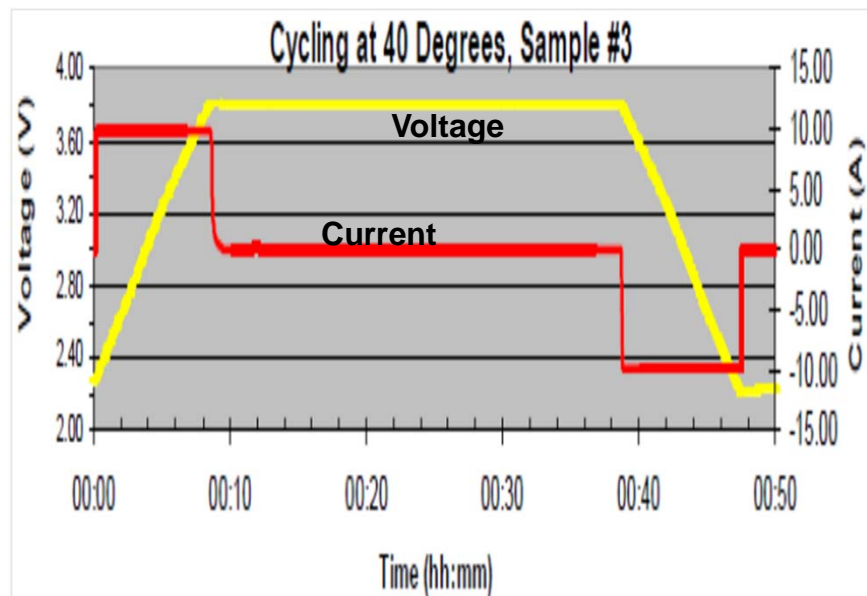
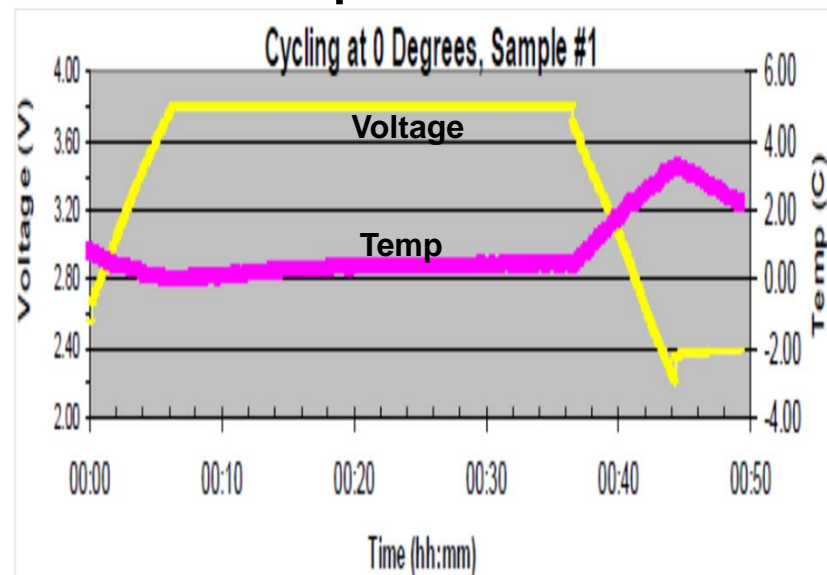
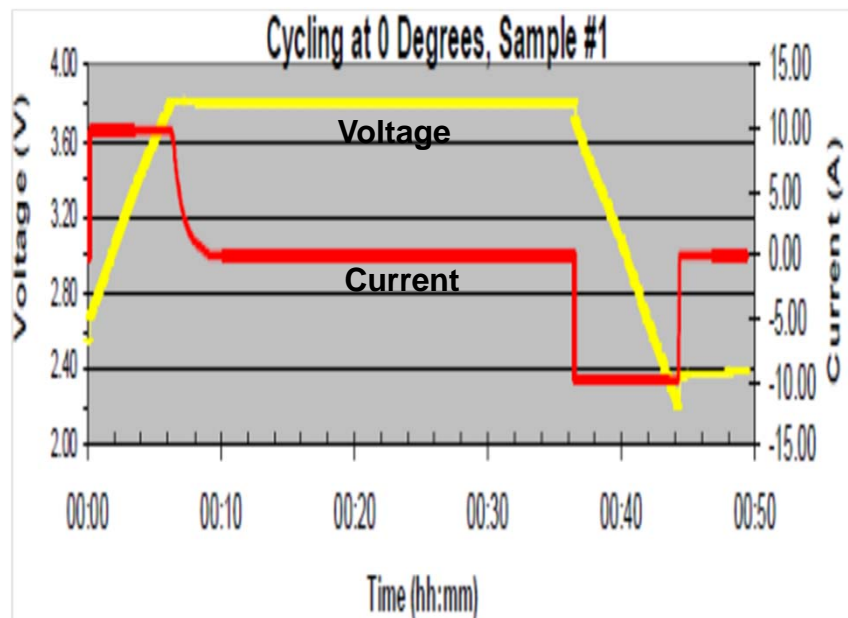


Test Number	Serial #	1st Cycle Capacity (Ah)	100th Cycle Capacity (Ah)	Capacity Change (%)	Capacity Change (Ah)
Protocol 1-1 (1.5A/10.0A)	3AL16-54	1.451	1.438	0.9%	0.013
Protocol 1-2 (1.5A/10.0A)	3AL16-56	1.469	1.463	0.4%	0.006
Protocol 1-3 (1.5A/10.0A)	3AL16-55	1.459	1.433	1.8%	0.026
Protocol 2-1 (5.0A/10.0A)	3AL16-57	1.314	1.310	0.3%	0.004
Protocol 2-2 (5.0A/10.0A)	3AK16-7	1.396	1.374	1.6%	0.022
Protocol 2-3 (5.0A/10.0A)	3AK16-9	1.413	1.399	1.0%	0.014
Protocol 3-1 (7.5A/10.0A)	3AK16-6	1.420	1.402	1.3%	0.018
Protocol 3-2 (7.5A/10.0A)	3AK16-8	1.424	1.425	-0.1%	-0.001
Protocol 3-3 (7.5A/10.0A)	3AK16-3	1.420	1.396	1.7%	0.024
Protocol 4-1 (10.0A/1.5A)	3AL16-54	1.491	1.488	0.2%	0.003
Protocol 4-2 (10.0A/1.5A)	3AL16-56	1.484	1.482	0.1%	0.002
Protocol 4-3 (10.0A/1.5A)	3AL16-55	1.496	1.494	0.1%	0.002
Protocol 5-1 (10.0A/3.0A)	3AL16-57	1.443	1.433	0.7%	0.010
Protocol 5-2 (10.0A/3.0A)	3AK16-7	1.458	1.456	0.1%	0.002
Protocol 5-3 (10.0A/3.0A)	3AK16-9	1.449	1.446	0.2%	0.003
Protocol 6-1 (1.5A/1.5A)	3AK16-6	1.456	1.451	0.3%	0.005
Protocol 6-2 (1.5A/1.5A)	3AK16-8	1.467	1.464	0.2%	0.003
Protocol 6-3 (1.5A/1.5A)	3AK16-3	1.459	1.458	0.1%	0.001

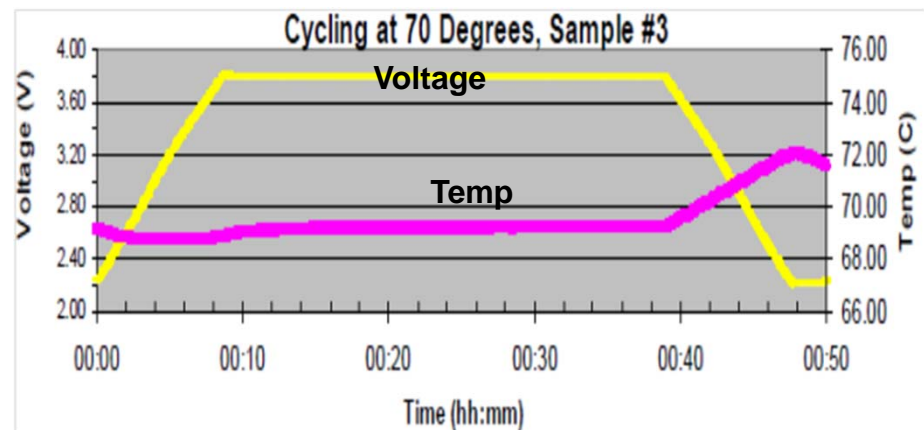
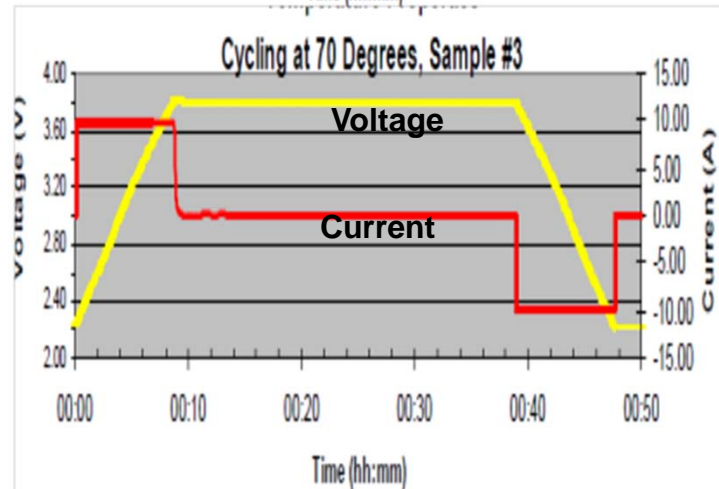
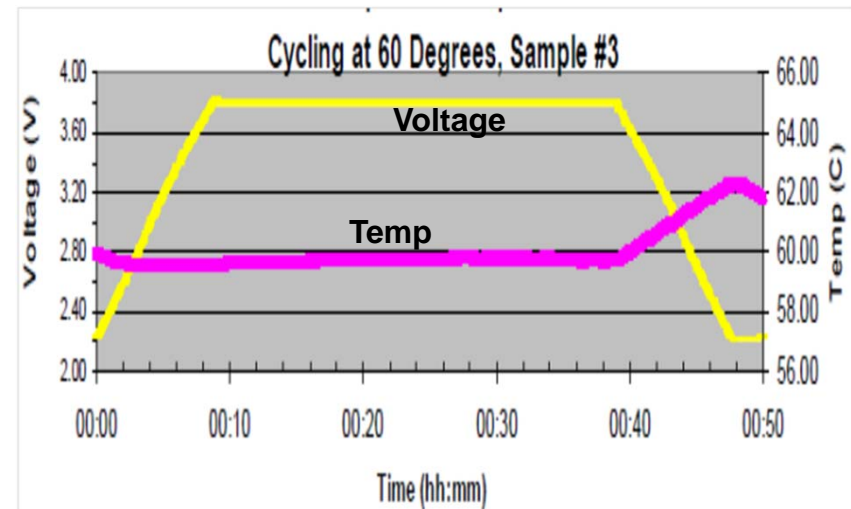
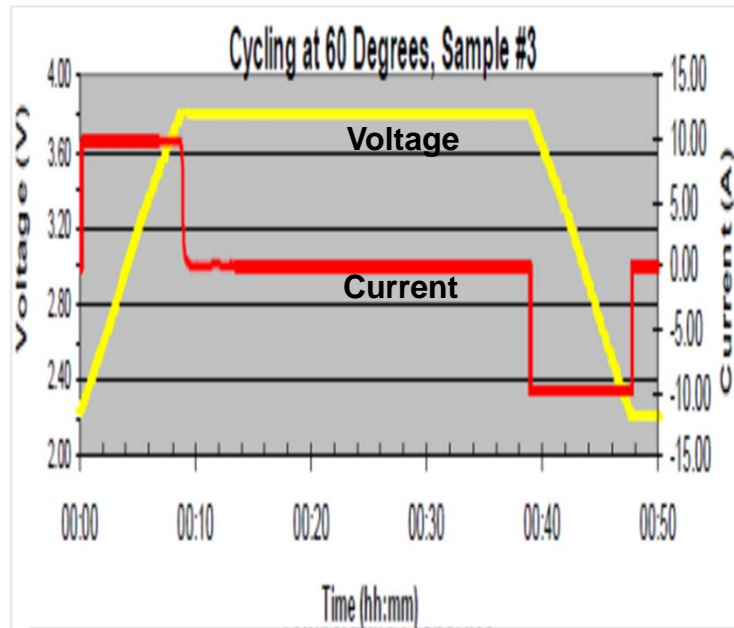
Performance at Various Temperatures



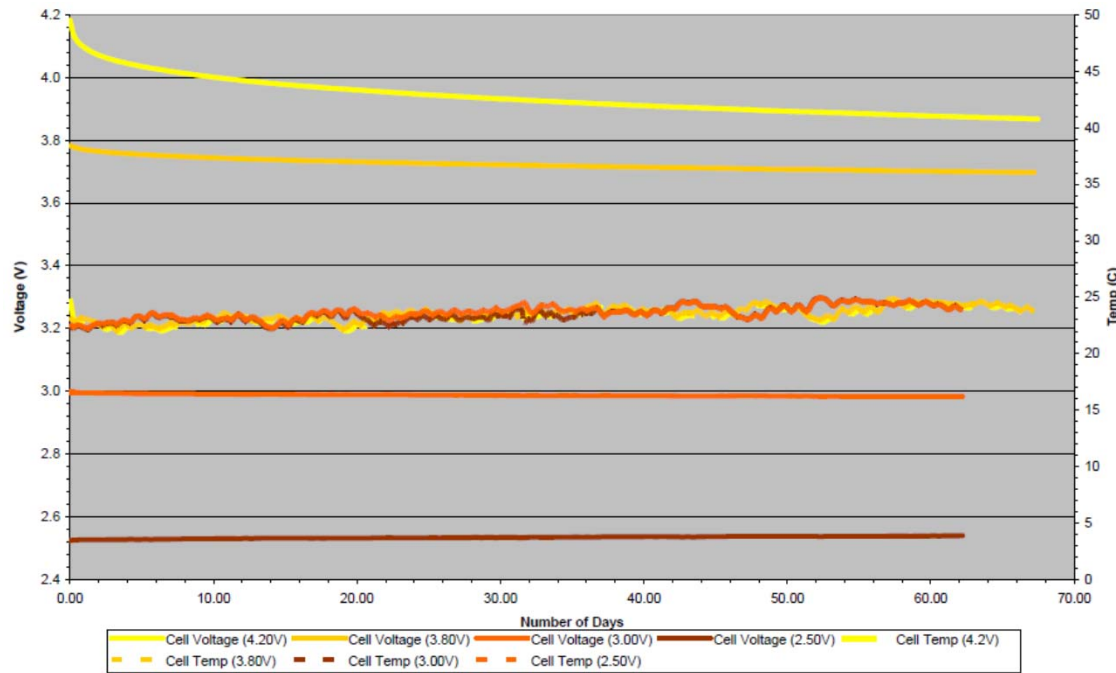
Performance at Various Temperatures



Performance at Various Temperatures



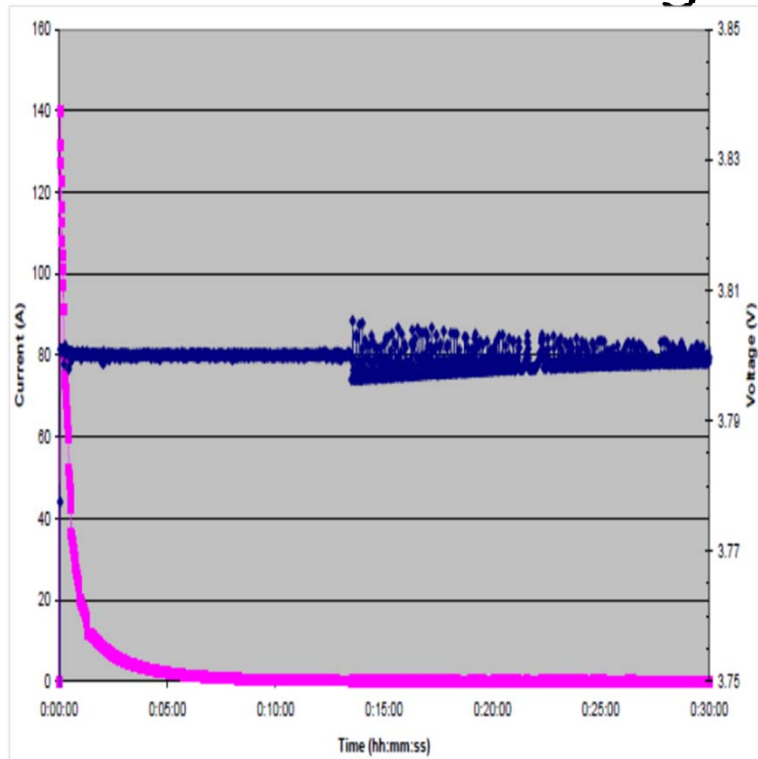
Self Discharge Test after Charge to Different SOC



Storage over 60 days

Sample #	Sample ID	Initial OCV (V)	Final OCV (V)	Capacity Retained (Ah)
1	16	4.183	3.868	1.724
2	17	3.784	3.698	1.425
3	18	2.996	2.984	0.675
4	19	2.524	2.540	0.306

High Current Charge

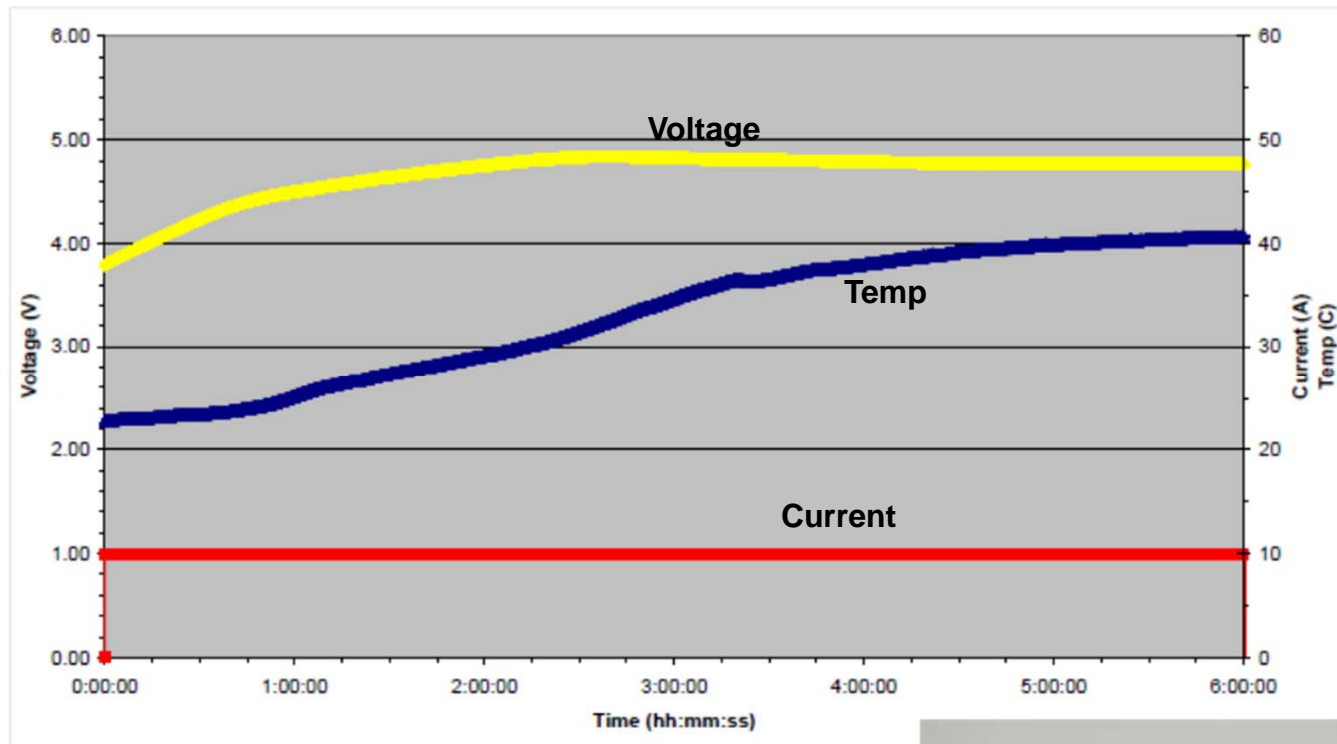


Sample #	Sample ID	Initial OCV (V)	Final OCV (V)	Capacity Retained (Ah)
1	28	3.800	3.758	1.536

100 A charge to 3.8 V and held in storage for 7 days.
Discharged at 10 A to determine capacity retention.

Safety Tests

Overcharge Test

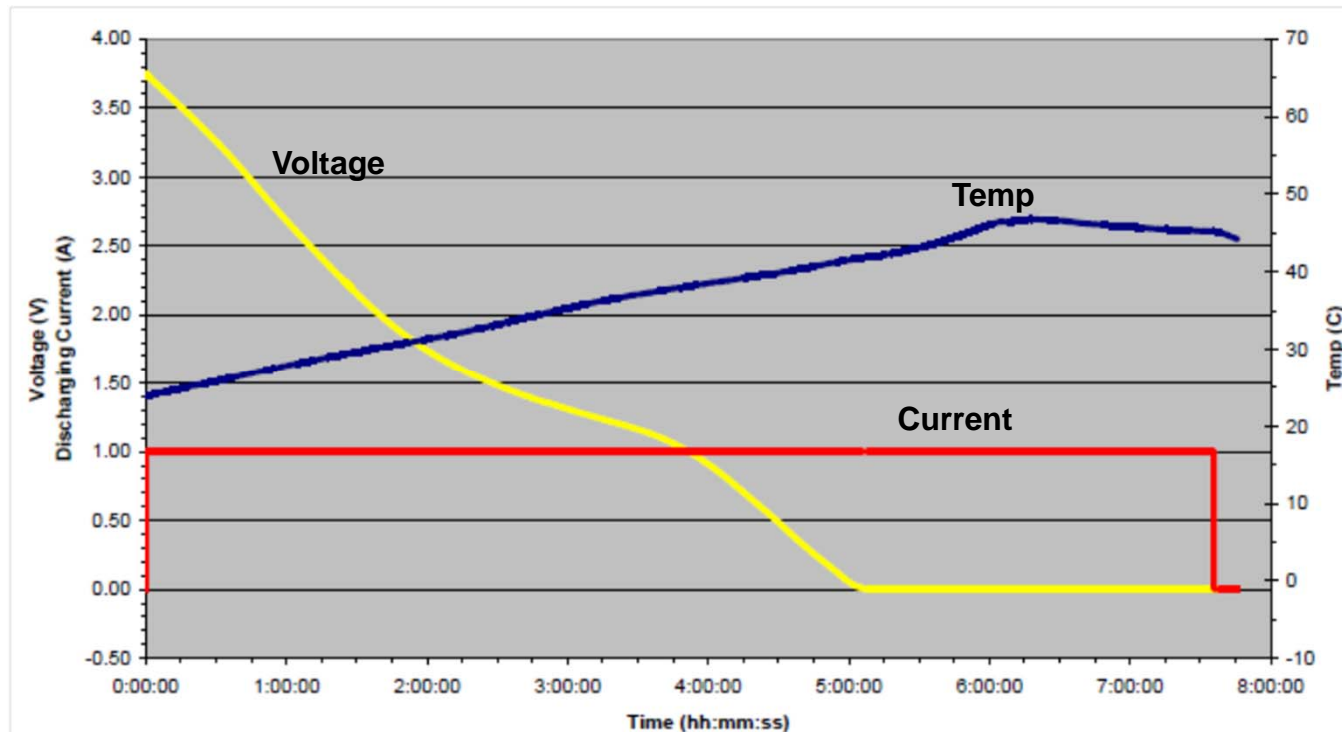


Overcharge a fully charge supercap to 20 V with 1 A current

Charge Current (A)	Final Voltage (V)	Initial OCV (V)	Maximum Temp (°C)	Notes
1	4.769	3.791	40.7	No Fire, Rupture, Smoke, or Vent
1	4.766	3.781	40.5	No Fire, Rupture, Smoke, or Vent



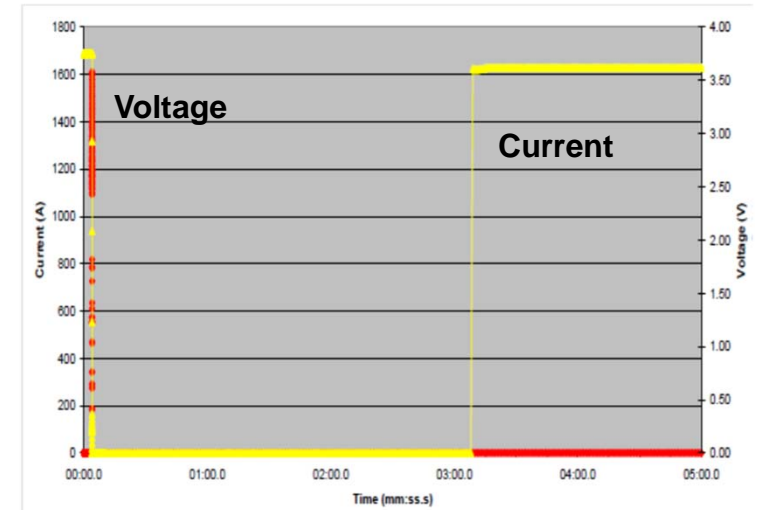
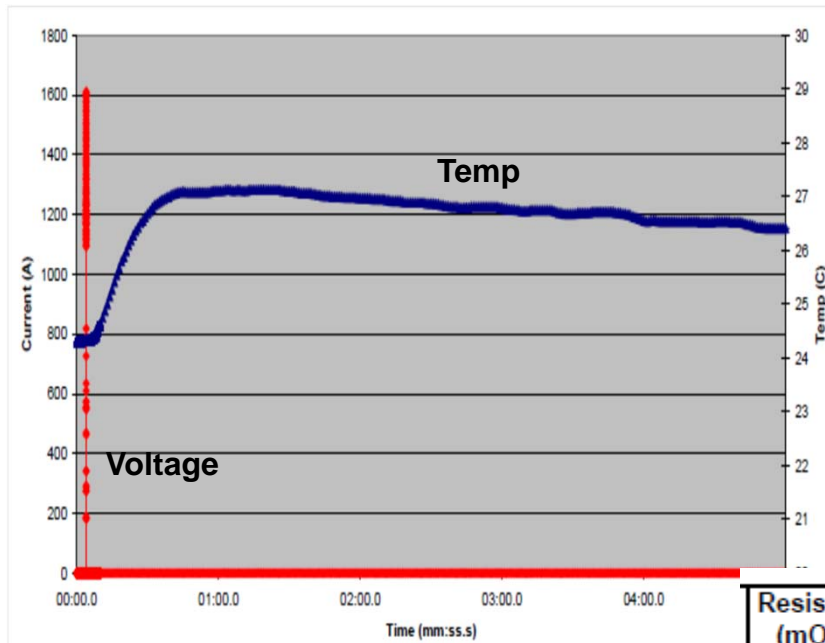
Overdischarge Test



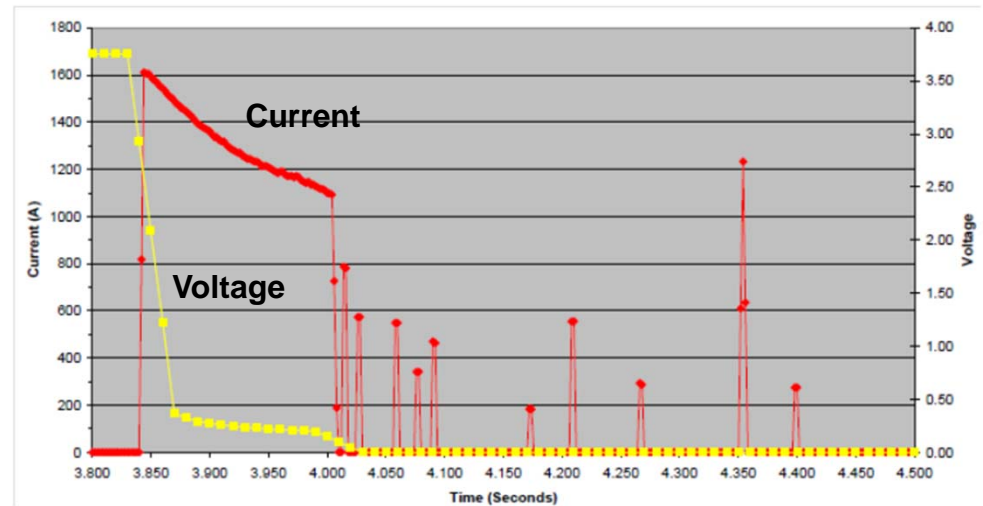
Overdischarge to 0 V with 1 A current

Cell bloated, no vent, smoke or fire.

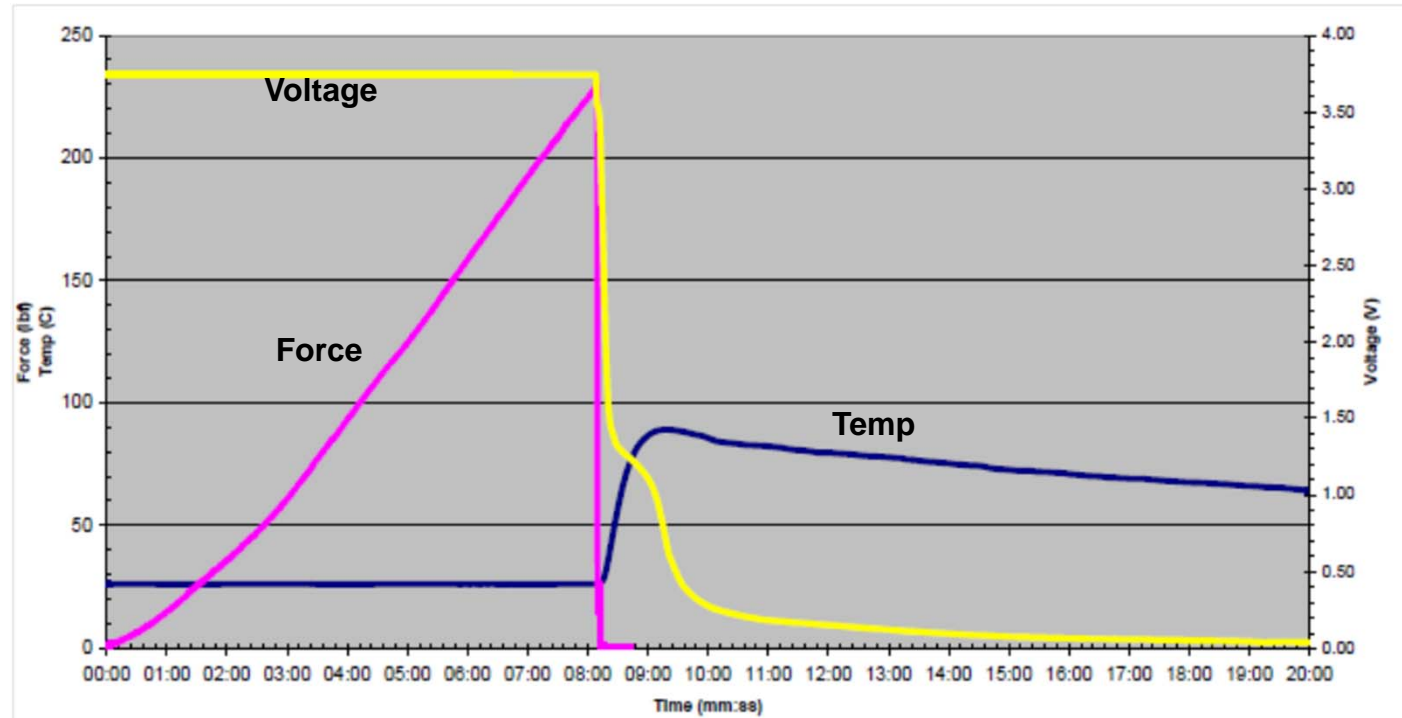
External Short Test



Resistance (mOhm)	Initial OCV (V)	Maximum Temp (°C)	Maximum Current (A)	Notes
0.85	3.754	27.1	1611	No Fire, Rupture, Smoke, or Vent
0.85	3.762	29.3	1868	No Fire, Rupture, Smoke, or Vent

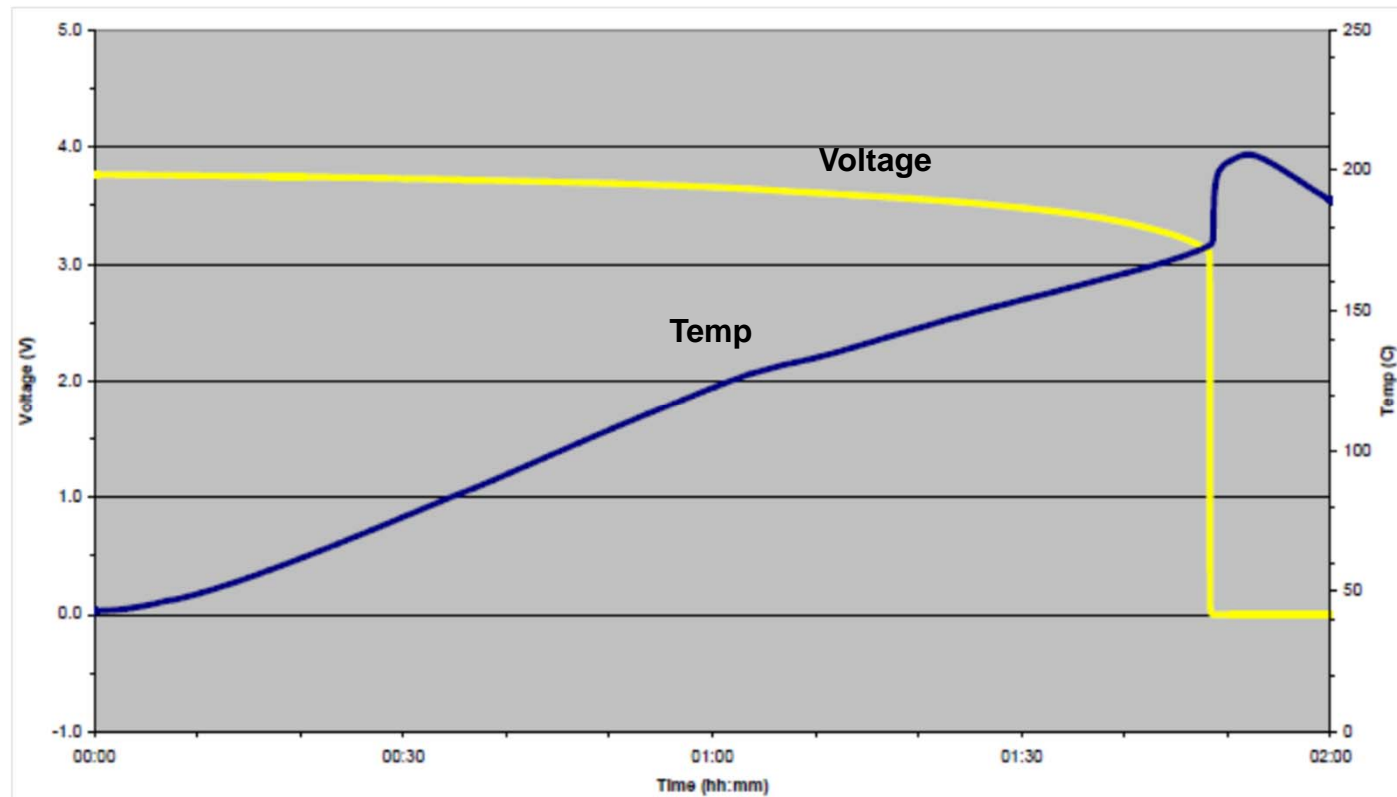


Simulated Internal Short



Sample ID	Initial OCV (V)	Maximum Temp (°C)	Notes
24	3.743	89.0	Smoke, Vent, No Fire
26	3.758	97.6	Smoke, Vent, No Fire

Heat-to-Vent Test



Sample ID	Initial OCV (V)	Maximum Temp (°C)	Notes
14	3.764	205.7	Smoke, Vent, No Fire
15	3.777	207.2	Smoke, Vent, No Fire

Summary

- Li-ion supercaps performed as predicted.
- The supercaps displayed less than 1% capacity loss for the cycles tested.
- The performance at various temperatures showed that they were capable of performing even at temperatures as low as -30 deg C and as high as 70 deg C without any major loss of performance or compromise to safety.
- The supercaps accepted charge of up to 140 A. Although up to 200 A was tested, it was noted that this high current caused the cells to hit the upper end of charge voltage limit almost instantaneously.
- The safety tests indicated that the worst case event was a swelling of the cells.
- The heat-to-vent tests also showed that the supercaps vented at about 175 degrees C.

Future Work

- Carry out testing with supercaps for various applications.

Acknowledgment

PCTest Engineering for carrying out the tests
JSC Micro, Inc. for supplying the supercaps